A Comparative Study of Inspection Techniques for Array Packages

Jelila Mohammed
Christopher Green
NASA Electronic Parts and Packaging (NEPP)

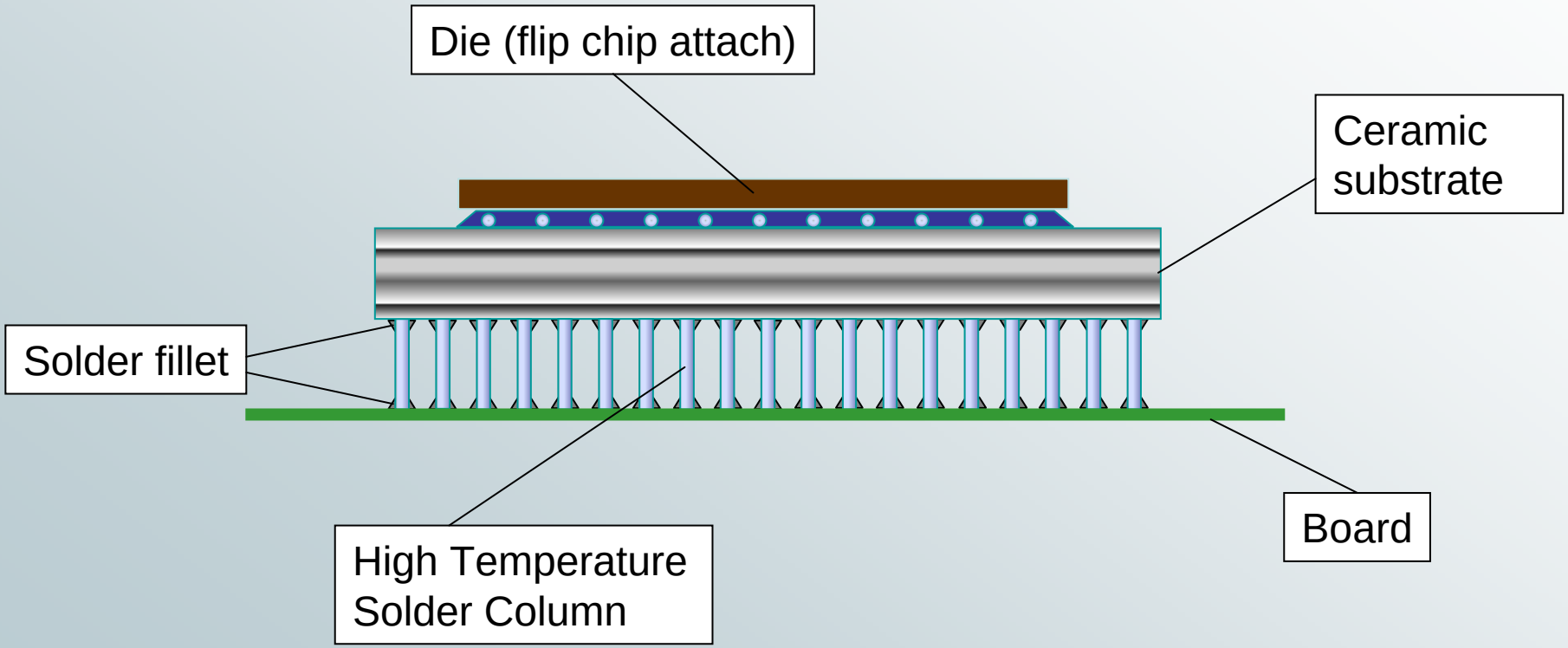
April 28, 2008

jelila.s.mohammed@nasa.gov

Column Grid Array Package

- Column Grid Array (CGA) is a method of chip scale packaging using high temperature solder columns to attach part to board
- Increasingly popular over quad flat pack (QFP) or ball grid array (BGA)
  - Allows for increased I/O's and higher density than the QFP
  - More thermo-mechanically reliable than a BGA because columns are more flexible than spheres, and they provide a high standoff between the component and the board

CGA Package Schematic



CGA Design Concerns

- Environmental Stresses
  - Temperature differential between the device and the board
  - Additional heat generated by the operating device
  - Extreme thermal and mechanical conditions due to spaceflight
  - Mismatch in CTE of the materials used
- Workmanship Challenges
  - Handling of “soft” solder columns that can bend easily
  - Alignment during PCB assembly
  - Fillet formation between the column and pad on PCB
  - Inspection of internal columns in large arrays

NEED GOOD INSPECTION TECHNIQUES FOR THESE PACKAGES

Inspection Concerns

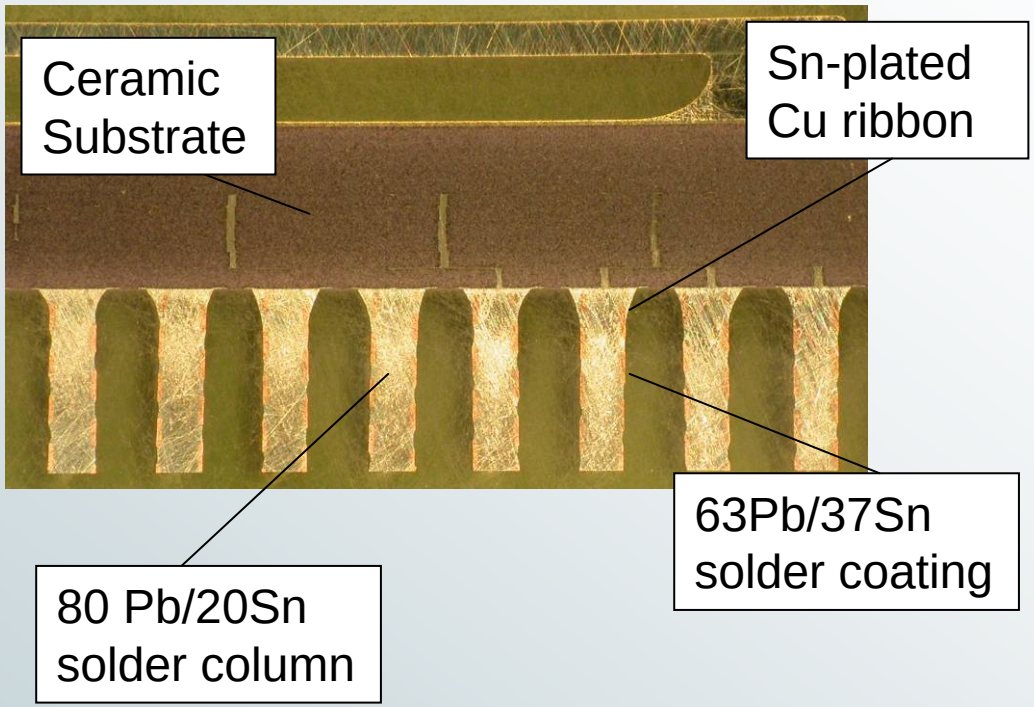
- Common assembly issues are:
  - Bent pins
  - Voids in joints
  - Poor wetting (solder fillet)
  - Contamination
  - Cold solder joints
  - Mis-alignment
  - Bridging/shorting
- Conventional PCB inspection techniques may miss these defects in a large array

Investigation Plan

- CGA daisy chained packages were obtained
- Two different column styles
- Parts were assembled to flight like PCBs
- Test boards were environmentally stressed
- Various inspection techniques were compared:
  1. Optical endoscope
  2. Real time X-ray
  3. Computed tomography (in progress)
  4. Fiber optic endoscope
  5. X-ray laminography (future work)
  6. C-SAM (future work)
- Investigation is ongoing – final results to be published on NEPP website (http://nepp.nasa.gov)

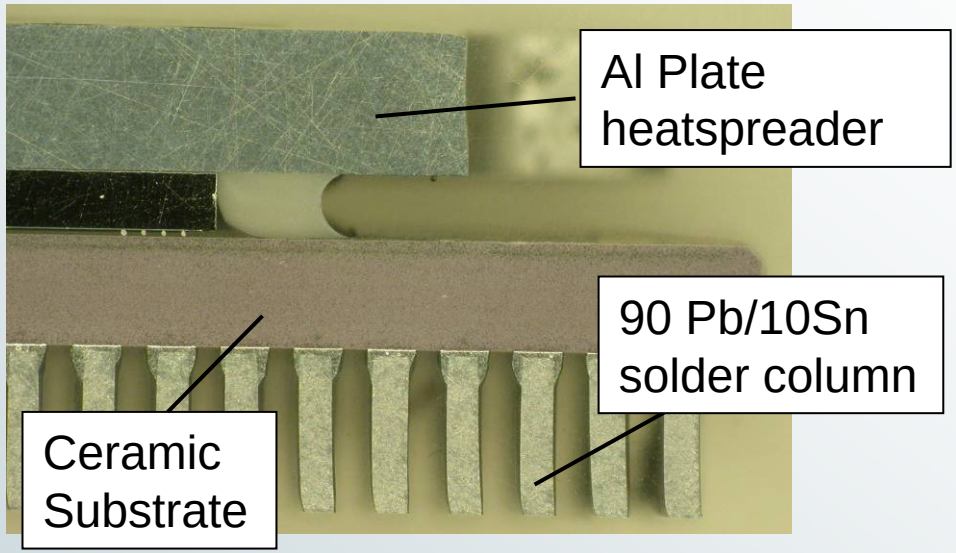
Test Device – Reinforced Column

- Daisy chained 484-pin CGA parts assembled onto test board
- Cu-reinforced columns
- Board was thermally and mechanically stressed



Test Device – Straight Column

- Daisy chained 1144-pin CGA parts assembled onto 2 test boards
- Workmanship defects were designed in during layout and assembly
- Board was thermal cycled

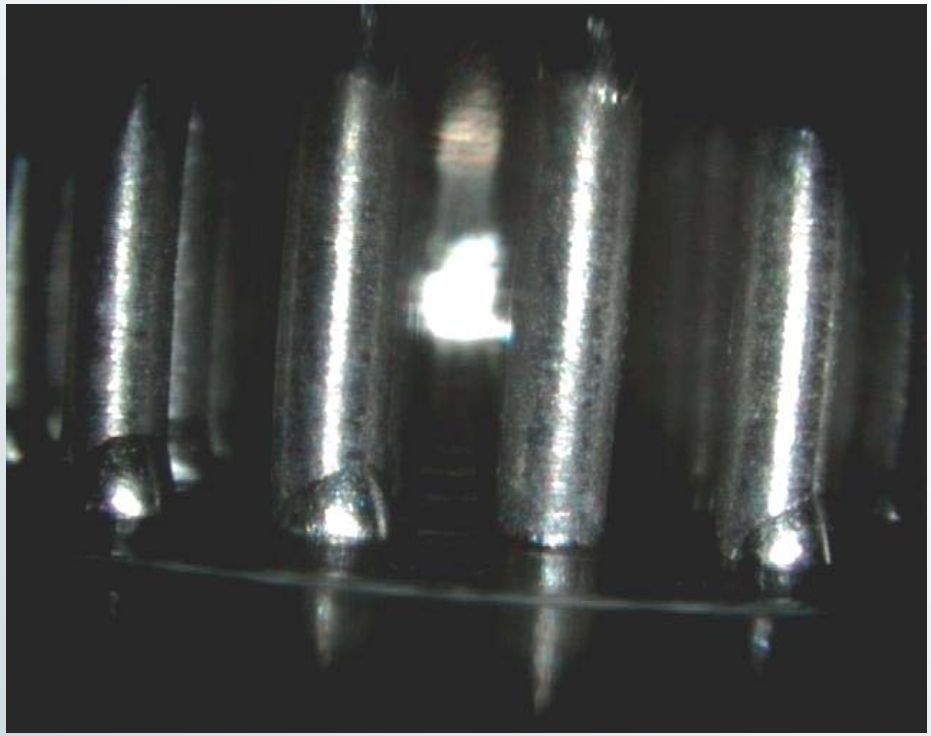


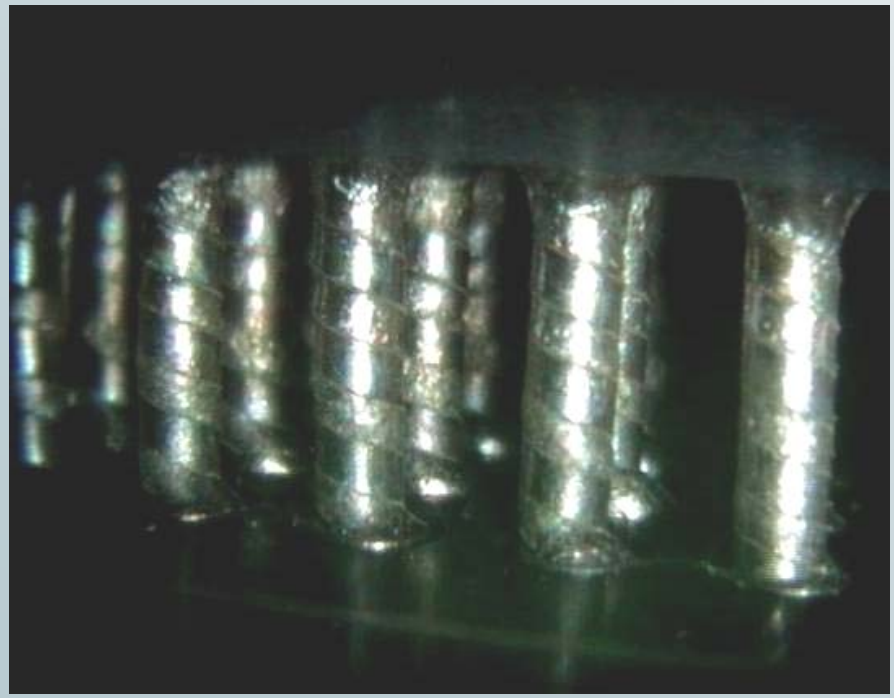
1. Optical Microscopy Inspection

- Inspected boards using an optical endoscopic microscope at GSFC
- Uses an endoscope with a lens enclosed in a mirrored tip, allowing a CCD camera to view underneath a CGA part
- Shows the solder columns in true color
- Using external lighting and adjusting the focus, an entire row of columns can be illuminated

Optical Microscopy Results

Aids in inspection of column alignment





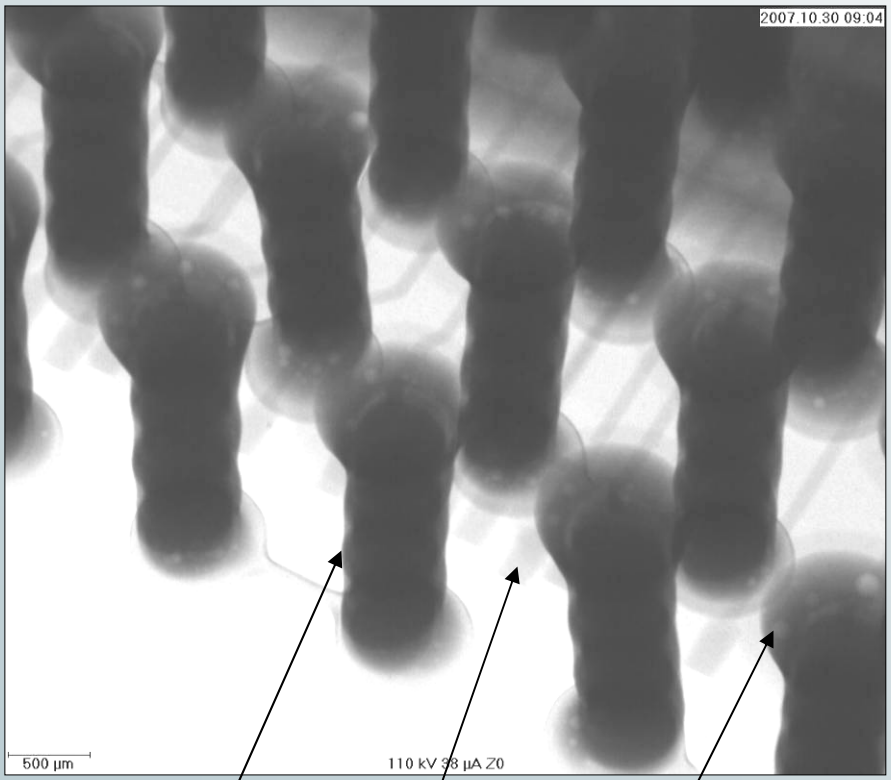
True color imaging of columns and solder joints indicates good solder quality

2. Real Time X-ray Inspection

- Inspected boards using an X-ray tool at CALCE Microanalysis Laboratory (University of Maryland)
- Provides real time 2-D X-ray images
- Board can be moved in x, y, and z directions
- Rotation of stage and detector allows for full inspection of each individual column and all solder joints
- 22” x 24” inspection area and180kV max tube voltage

X-ray Results

Reinforced column testboard



- Most of the defects observed were voids in the solder joints
- Other features could be seen
  - Copper reinforcement of the column
  - Metal traces on the board

3. Computed Tomography Inspection

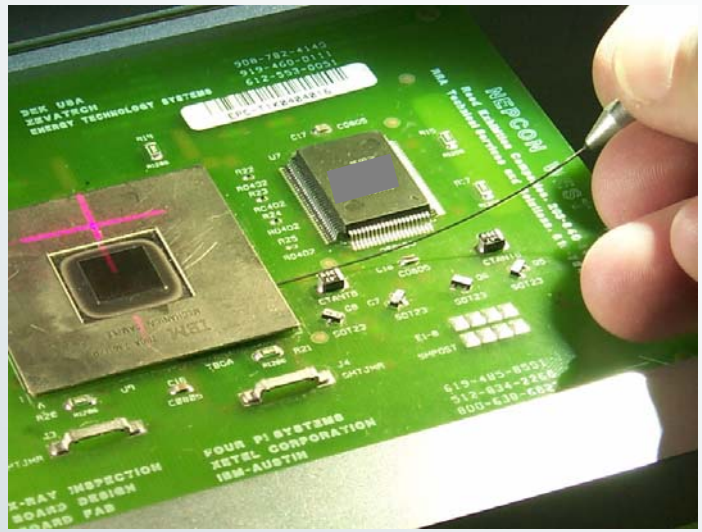
- The real time X-ray tool also has the capability to perform computed tomography (CT)
- Device is rotated around the x-axis, while suspended on a rod between the X-Ray source and detector
- Software captures many X-ray images and reconstructs a three-dimensional model of the object
- Can non-destructively simulate a cross section

Computed Tomography Results

- High resolution CT imaging requires a low clearance between the X-ray source and the device that is difficult to achieve if rotating a PCB
- May be able to perform the CT scan on a larger board if the board is cut with the CGA package still attached
- Limitations
  - Time consuming
  - May still damage the board or stress the solder joints during cutting
  - The CGA may be too large to provide an un-distorted 3-D rendering – may only be able to image a small section of the array
- CT scan not yet completed – to be published on NEPP website with final results (http://nepp.nasa.gov)

4. Fiber Optic Endoscope

- Inspected boards using a fiber optic endoscope at NASA Langley Research Center
- Feeds a fiber optic bundle down the entire row of columns (~3000 fibers, some for imaging, some for lighting)
- Additional lamps and stage were added for lighting and stability of sample
- All columns are visible throughout the array



Fiber Optic Results

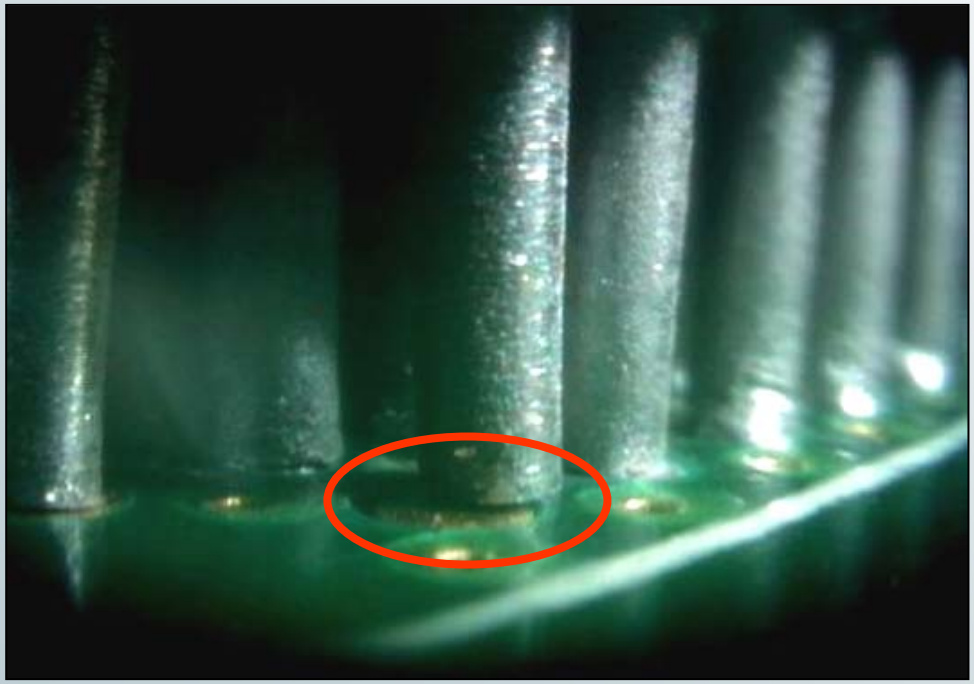
- Fiber bundle is basically rigid – not designed to bend
- Can inspect solder fillets, column alignment, and view entire array
- Color and resolution are poor

Image of center part of array, showing inner columns

Recommendation

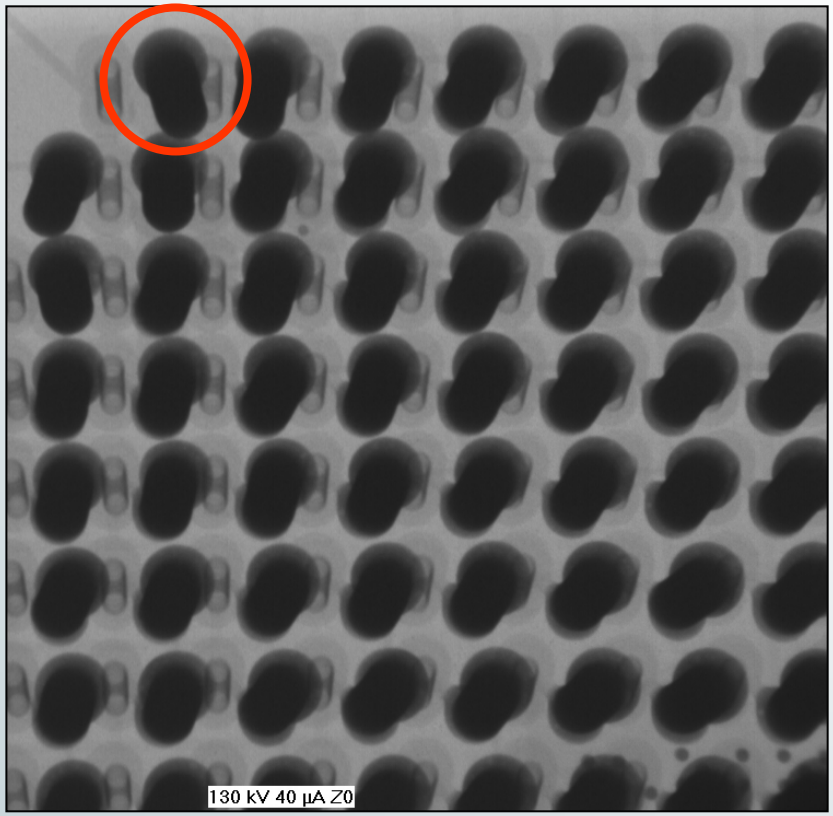
- Each inspection technique has advantages and disadvantages
- A combination approach is required for a thorough inspection of a CGA assembly

Defect - Solder Wetting

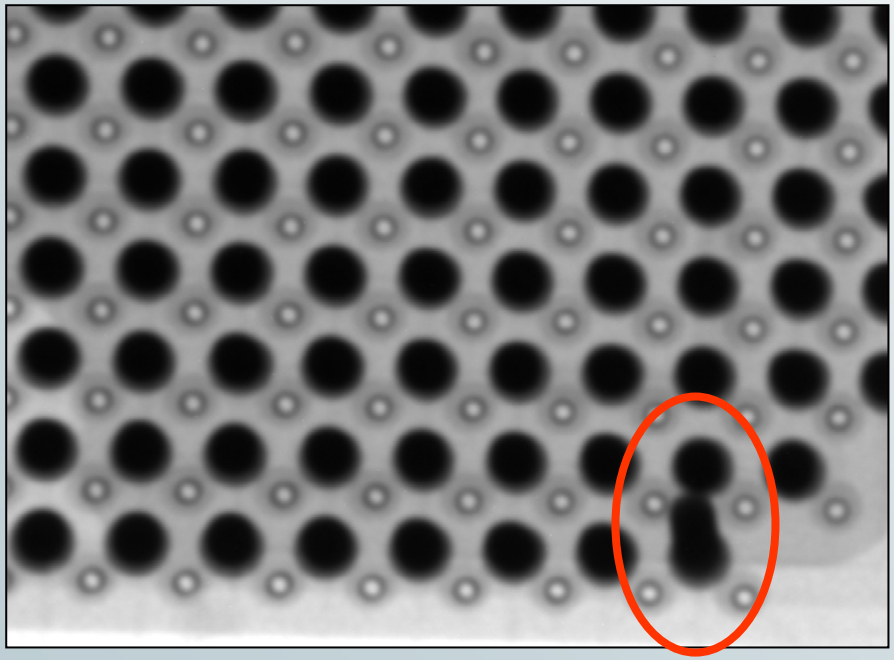


Optical inspection shows column is lifted off pad and has no solder attach at all.

X-Ray inspection does not indicate the column is abnormal.

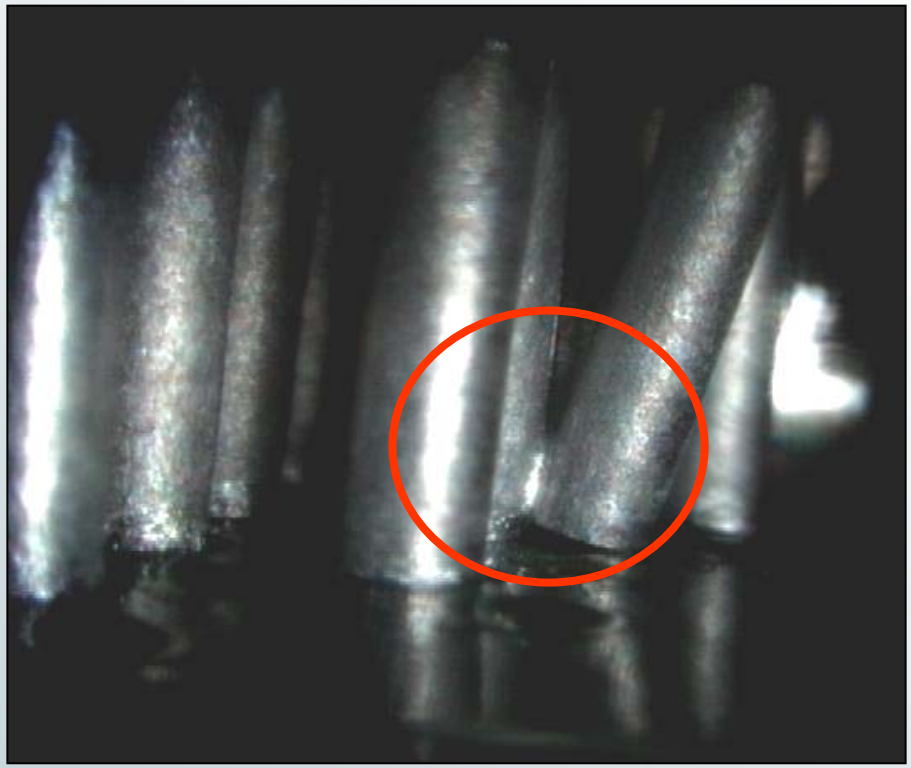


Defect - Bent/Shorted Columns

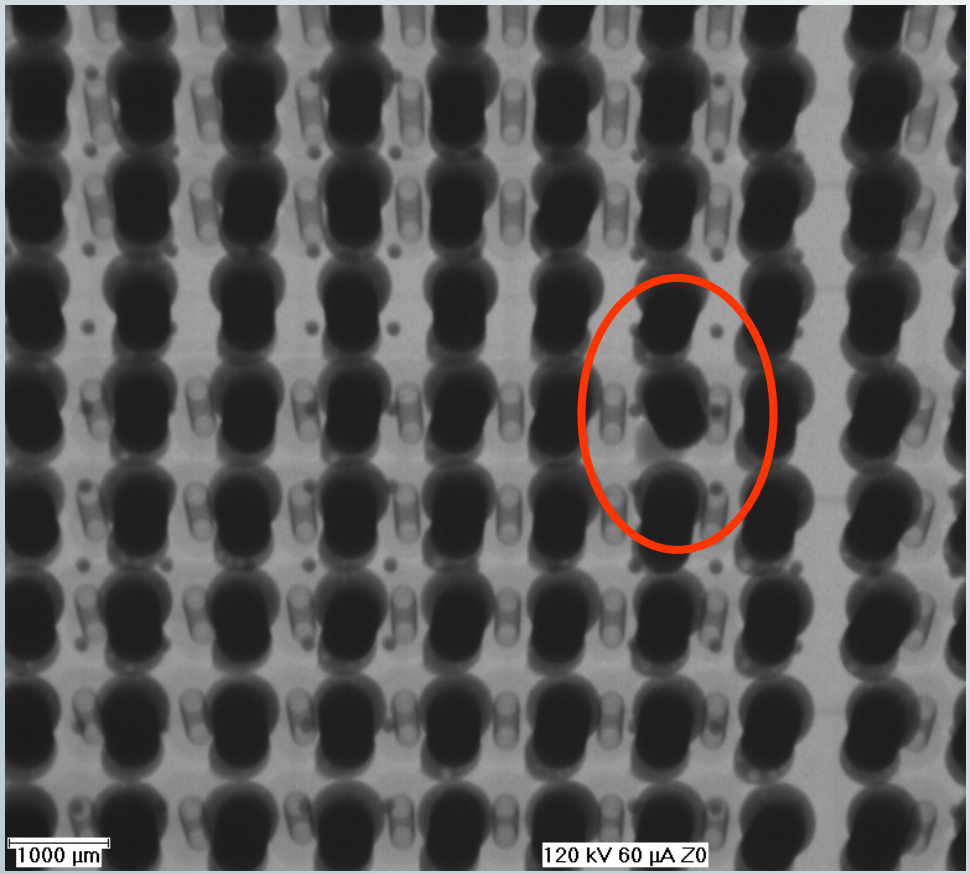


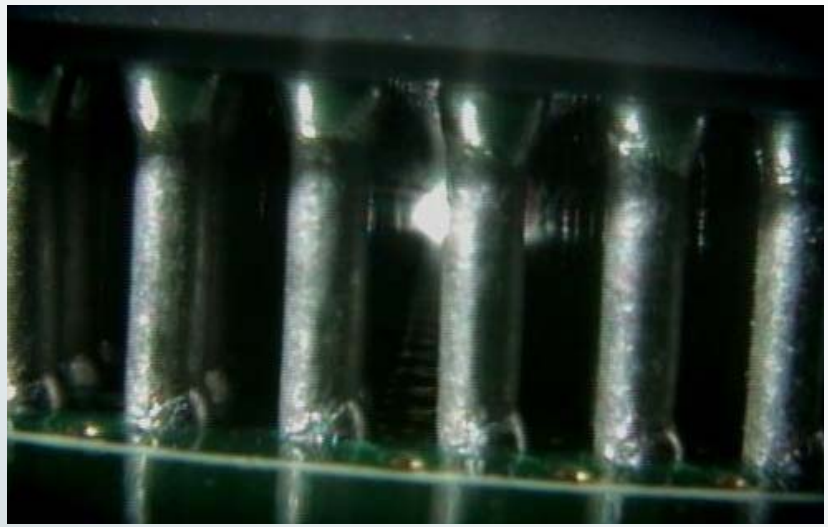
X-ray inspection shows the bent pin, but the short cannot be confirmed

Optical inspection indicates that one pin is shorted to another



Defect - Bent Column





X-ray shows bent column in center of array, but inspection with the optical scope cannot clearly show center part of array.

Comparison Table

Overview of ability of inspection tools to reveal the defects listed below

Defect / Inspection Technique	Optical	X-Ray	CT	Fiber Optic
Bent pins	✓	✓	✓	✓
Voids	✓	✓	✓	✓
Poor solder fillet coverage	✓	✓	✓	✓
Cold solder joints	✓	✓	✓	✓
Contamination	✓	✓	✓	✓
Mis-alignment	✓	✓	✓	✓
Shorting	✓	✓	✓	✓

Conclusions

- Techniques evaluated were: optical endoscope, real time X-ray, computed tomography, and fiber optic endoscope
- A combination of inspection techniques will allow for detection of:
  - Bent pins
  - Voids in solder joints
  - Poor solder fillet coverage
  - Contamination
  - Cold solder joints
  - Mis-alignment of part
  - Bridging/shorting
- In-circuit testing should accompany inspection to help indicate failures
- No single inspection technique can perform a complete analysis

Acknowledgements

- NASA Electronic Parts and Packaging (NEPP) Program
- NASA Goddard Space Flight Center
- NASA Langley Research Center
- University of Maryland CALCE